

# Health Guidance:

## Initial Management in a Hospital Setting of Persons Contaminated With Radioactive Materials and Exposed to Radiation

February 22, 2007

This document will be updated as new information becomes available. The current version can always be viewed at <http://www.dhss.mo.gov>

The Missouri Department of Health & Senior Services (DHSS) is now using 4 types of documents to provide important information to medical and public health professionals, and to other interested persons:

**Health Alerts** convey information of the highest level of importance which warrants immediate action or attention from Missouri health providers, emergency responders, public health agencies, and/or the public.

**Health Advisories** provide important information for a specific incident or situation, including that impacting neighboring states; may not require immediate action.

**Health Guidances** contain comprehensive information pertaining to a particular disease or condition, and include recommendations, guidelines, etc. endorsed by DHSS.

**Health Updates** provide new or updated information on an incident or situation; can also provide information to update a previously sent Health Alert, Health Advisory, or Health Guidance; unlikely to require immediate action.

Health Guidance  
February 22, 2007

**FROM: JANE DRUMMOND  
DIRECTOR**

**SUBJECT: Initial Management in a Hospital Setting of Persons Contaminated With Radioactive Materials and Exposed to Radiation Following the Explosion of a Dirty Bomb**

The purpose of this Health Guidance is to remind hospitals of the need to be prepared to triage, decontaminate, and treat persons exposed to radioactive materials from a dirty bomb explosion or other radiological event. It also is intended to provide practical information that hospitals may utilize as they develop or update their emergency response plans and train their staff. The Missouri Department of Health and Senior Services (DHSS) is not currently aware of any specific plans by terrorists to detonate a dirty bomb in Missouri; however, such a device is a potential terrorist weapon, and hospitals and other medical facilities must be ready to immediately respond should such an event occur.

A potential weapon that could be utilized by terrorists is a dirty bomb, which is one type of radiation dispersal device (RDD). A dirty bomb is a mix of explosives with radioactive powder or pellets. When the explosives are set off, the blast carries radioactive material into the surrounding area. The main danger is from the explosion, which can result in serious injuries and deaths. The radioactive materials used in a dirty bomb will probably not create enough radiation exposure to cause immediate serious illness, except perhaps to those persons who are very close to the blast site. However, the radioactive dust and smoke, which spread farther away, could be dangerous to health if inhaled or ingested.

**Following detonation of a dirty bomb, all hospitals in the area must be prepared to immediately receive patients with external (and potentially internal) radioactive contamination. Some of these individuals may also have traumatic and/or burn injuries (possibly severe) related to the explosion. In addition, many other uninjured but concerned individuals, some of whom may be contaminated, will likely be presenting for evaluation. Hospitals outside the immediate area could also see victims from the event (e.g., injured persons who are transferred to these more distant hospitals because hospitals closer to the incident are full, or persons with no or minor injuries who have transported themselves out of the area of the event before seeking medical care). Additionally, medical facilities other than hospitals (e.g., urgent care centers, outpatient clinics, private physicians' offices) could have affected persons present for evaluation/care. Some key points are the following:**

- **Very Important: If immediate action is not taken to secure the facilities to which contaminated persons will be presenting, these facilities can very quickly become contaminated with radioactive material.**
- All seriously injured patients (or patients with other life-threatening medical conditions) should be **medically stabilized before issues of radiation exposure/contamination and decontamination are considered.** However, while the patient is being medically stabilized, appropriate steps must be taken to prevent contamination of medical staff and the area where this initial treatment is taking place.

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- In most cases, external contamination can be readily detected with survey instruments and readily removed. Decontamination (removal of contaminants) can be accomplished by removal of the victim's clothing and thorough, careful washing with warm water and soap, followed by a radiation survey to determine if the washing procedure was sufficiently effective. Except for victims with serious injuries or other life-threatening medical conditions, decontamination can be accomplished prior to admission to hospital emergency care.
- Psychological counseling should be available. Addressing the psychological effects of the event on patients (including concerns about exposure to radiation) must be an integral part of patient management.
- Anticipate the need to provide transport or shelter to persons who do not require immediate medical care following triage/decontamination.
- On-scene responders should not send uninjured persons who have no signs/symptoms of acute radiation syndrome (ARS) or other significant medical problems to hospitals. Individuals who are only externally contaminated, but not injured and with no evidence of ARS or significant illness, should be decontaminated at a facility other than a hospital to conserve hospital resources for those who need these resources. Contact information should be recorded for all exposed persons so that they can, as necessary, be contacted later to arrange medical evaluation.
- Following a dirty bomb explosion, public health and other government officials will be providing ongoing updated information to medical providers (e.g., geographic area affected, radionuclide data, radiation dose assessment).

**All hospitals must have a plan for responding to radiological emergencies. This plan must be periodically reviewed and periodically exercised. It must be stressed that if a radiological event occurs, there will be no time to prepare/update a plan and train appropriate personnel; this must be done in advance.**

**Guidance for hospitals in managing radiation emergencies associated with dirty bombs and other radiological events is available from the Radiation Emergency Assistance Center/Training Site (REAC/TS). REAC/TS can provide specific consultation on the medical management of the victims of radiation events. Their emergency number is 865/576-1005.**

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The document below entitled *Managing Radiation Emergencies: Guidance for Hospital Medical Management* provides guidance in managing radiation emergencies associated with dirty bombs and other radiological events. It was developed by REAC/TS, and is also available at <http://orise.orau.gov/reacts/guide/care.htm>. A second document from REAC/TS entitled *Hospital Triage in the First 24 Hours after a Nuclear or Radiological Disaster* is available at <http://orise.orau.gov/reacts/files/triage.pdf>.

Shortly after this Health Guidance document was issued, the U.S. Department of Health and Human Services (HHS) released comprehensive guidance on the clinical diagnosis and treatment of victims following a mass casualty radiological/nuclear event. This guidance, entitled **Radiation Event Medical Management (REMM)**, is meant to provide evidence-based, usable information with sufficient background and context to make complex issues understandable to those without formal radiation medicine expertise. The information and clinical protocols contained here (including a tool to calculate the estimated radiation dose a victim has received) can be very useful to clinicians, and will supplement the information found in this Health Guidance document. REMM can be accessed online at <http://www.remm.nlm.gov/index.html>. An option is to download the materials onto a computer hard drive, or onto a CD or other portable storage device (click on the link entitled "Download This Site").

The Centers for Disease Control and Prevention (CDC) has issued interim guidelines for hospital response to mass casualties from a radiological incident. The focus of these guidelines, which are available from CDC at

<http://www.bt.cdc.gov/radiation/pdf/MassCasualtiesGuidelines.pdf>, is on the unique aspects of a radiological event involving mass casualties.

Recommendations on the medical management of ARS, which were published in the *Annals of Internal Medicine*, are available at <http://www.annals.org/cgi/reprint/140/12/1037.pdf>.

The American Academy of Pediatrics has prepared a comprehensive document entitled *Pediatric Terrorism and Disaster Preparedness: A Resource for Pediatricians*. Chapter 6 of this document (“Radiological and Nuclear Terrorism”) provides a detailed discussion of the diagnosis and management of radiation-induced illness, especially as it affects children. The document is available at <http://www.ahrq.gov/research/pedprep/pedresource.pdf>.

Links to additional information on radiological events and their management can be found at [http://www.dhss.mo.gov/BT\\_Response/Nuclear\\_Med.htm](http://www.dhss.mo.gov/BT_Response/Nuclear_Med.htm).

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Hospitals may wish to utilize these materials as they develop or update their response plans and train their staff. The goal of hospital radiation training should be to enable participants to provide prompt and appropriate care for victims of radiological incidents while minimizing radiation exposure to both victims and providers. It should also enable facilities to prevent the spread of radioactive contamination. Training should include, though not necessarily be limited to, the following:

- Introduction to radiological/nuclear terrorism.
  - Fundamentals of radiation.
  - General hospital preparedness for radiological incidents.
  - Detection and measurement of radiation/contamination.
  - Preventing the spread of radioactive contamination and reducing radiation exposure to victims and providers. Included here would be proper decontamination procedures for adults and children, and the appropriate use of personal protective equipment (PPE).
  - Clinical management of mass radiological casualties, including evaluation of radiation exposure and internal contamination, and treatment of radiation-induced illness.
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Questions should be directed to DHSS’s Office of Community and Public Health Emergency Coordination (OCPHEC) at **573/751-6161**, or **800-392-0272**. FAX number is 573/562-5348.

## Managing Radiation Emergencies: Guidance for Hospital Medical Management

Radiation Emergency Assistance Center/Training Site (REAC/TS)

<http://orise.orau.gov/reacts/guide/care.htm>

### Contents

Managing Emergency Care of Patients Contaminated with Radioactive Materials

Hospital Emergency Care of the Radiation Accident Patient

Radiation Injury

- Local Injury
- Acute Radiation Syndrome
- Internal Contamination

## Managing Emergency Care of Patients Contaminated with Radioactive Materials

### Notification and Accident Verification

When the hospital receives a call that a radiation accident victim is to be admitted, a planned course of action should be followed. The individual receiving the call should get as much information as possible, including the following:

1. Number of accident victims
2. Each victim's medical status and mechanism of injury
3. If victims have been surveyed for contamination
4. Radiological status of victims (exposed vs. contaminated)
5. Identity of contaminant, if known
6. Estimated time of arrival

If any doubt about contamination exists, assume the victim is contaminated until proven otherwise. Advise ambulance personnel of any special entrance to the emergency department for the radiation accident victim. If the accident notification comes from a source other than usual emergency communications, get a call-back number and verify the accident prior to assembling the radiological emergency response team and preparing for patient admission.

### The Radiological Emergency Response Team

Each member of this team should be familiar with the hospital's written plan and be required to participate in scheduled drills. More frequent drills (quarterly or semiannually) should be considered by subgroups such as decontamination, triage, or radiological monitoring. Special training must be instituted to accommodate staff turnover. Training should also be part of the hospital inservice program and should include EMTs and paramedics since they play an important role in assisting the

emergency department staff through notification procedures before arrival and proper transport of radiation accident victims.

Radiological Emergency Response Team	
Personnel Role	Function
Team coordinator	Leads, advises, and coordinates
Emergency physician	Diagnoses, treats, and provides emergency medical care; can also function as team coordinator or triage officer
Triage officer	Performs triage
Nurse	Assists physician with medical procedures, collection of specimens, radiological monitoring, and decontamination; assesses patient's needs and intervenes appropriately
Technical recorder	Records and documents medical and radiological data
Radiation safety officer	Supervises all aspects of monitoring and contamination control
Radiation safety personnel	Monitors patient and area and advises on contamination and exposure control; maintains survey equipment
Public information officer	Releases accident information to public media
Administrator	Coordinates hospital response and assures normal hospital operations
Security personnel	Secures the radiation emergency area and controls crowds
Maintenance personnel	Aids in preparation of the radiation emergency area for contamination control
Laboratory technician	Provides routine clinical analysis of biological samples

### Goals of Contamination Control

The goals of contamination control are to prevent spread of radioactive materials from:

A. The patient

*In most circumstances the victim will be the source of the contamination; however, in rescue and extrication, some contamination may have been transferred to others.*

B. The rescue personnel

C. The gurney and equipment used in patient care (stethoscope, BP cuff, etc.)

D. The ambulance

This contamination can be transferred to:

1. Care providers as they touch or move the patient to correct the medical problem
2. The equipment used to assess the patient's condition and to treat the medical emergency
3. The surrounding area (treatment gurney, floor, etc.)
4. In rare cases where dust or powders are present, the air could contain radioactive particles

### **Techniques of Contamination Control**

1. Set up a controlled area large enough to hold the anticipated number of victims.
2. Prevent tracking of contaminants by covering floor areas (see below under "Preparing the Treatment Area for Contamination Control") and monitoring at exits of controlled areas.
3. Restrict access to the controlled area.
4. Monitoring *anyone* or *anything* leaving the controlled area.
5. Use strict isolation precautions, including protective clothing (see below under "Response Team Preparation") and double bagging.
6. Use a buffer zone or secondary control line for added security.
7. Control waste by using large, plastic-lined containers for clothing, linens, dressings, etc.
8. Control ventilation (see below under "Preparing the Treatment Area for Contamination Control").
9. Change instruments, outer gloves, drapes, etc., when they become contaminated.
10. Use waterproof materials to limit the spread of contaminated liquids; for example, waterproof aperture drapes.

### **If Radioactive Contamination Is Discovered After Patient Has Been Admitted**

1. Continue attending to the patient's medical needs.
2. Secure entire area where victim and attending staff have been.
3. Do not allow anyone or anything to leave area until cleared by the radiation safety officer.
4. Establish control lines, and prevent the spread of contamination.
5. Completely assess patient's radiological status.
6. Personnel should remove contaminated clothing before exiting area; they should be surveyed, shower, dress in clean clothing, and be resurveyed before leaving area.

### **Response Team Preparation**

#### Protective clothing

The purpose of protective clothing is to keep bare skin and personal clothing free of contaminants. Members of the radiological emergency response teams should dress in surgical clothing (scrub suit, gown, mask, cap, eye protection, and gloves). Water-

proof shoe covers also should be used. All open seams and cuffs should be taped using masking or adhesive tape. Fold-over tabs at the end of each taped area will aid removal. Two pairs of surgical gloves should be worn. The first pair of gloves should be under the arm cuff and secured by tape. The second pair of gloves should be easily removable and replaced if they become contaminated. A radiation dosimeter should be assigned to each team member and attached to the outside of the surgical gown at the neck where it can be easily removed and read. If available, a film badge or other type of dosimeter can be worn under the surgical gown. A waterproof apron can also be worn by any member of the team using liquids for decontamination purposes.

This protective clothing is effective in stopping alpha and some beta particles but not gamma rays. Lead aprons, such as those used in the x-ray department, are not recommended since they give a false sense of security -- they will not stop most gamma rays.

### **Preparing the Treatment Area for Contamination Control**

If possible, select a treatment room near an outside entrance. Clear the area of visitors and patients. Remove or cover equipment that will not be needed during emergency care of the radiation accident victim.

Several large plastic-lined waste containers will be needed. The treatment table should be covered with several layers of waterproof, disposable sheeting. Plastic bags in all sizes will be needed and should be readily available.

Survey instruments should be checked and ready for use before the patient arrives. Background radiation levels should be documented.

The treatment team should be prepared to meet the patient at the ambulance where the patient can be transferred to the prepared treatment gurney.

#### Covering floor areas

Rolls of brown wrapping paper or butcher paper three to four feet wide can be unrolled to make a path from the ambulance entrance to the decontamination room. Ordinary cloth sheets or square absorbent pads can be used if paper is unavailable. Whatever the floor covering, it should be taped securely to the floor. This route should then be roped off and marked to prevent unauthorized entry. The floor of the decontamination room or treatment area should be covered in a similar way if time allows. This will make cleanup of the area easier.

A control line should be established at the entrance to the decontamination room. A wide strip of tape on the floor at the entrance should be marked clearly to differentiate the controlled (contaminated) from the non-controlled (uncontaminated) side.

#### Control ventilation

While it may be desirable that the room, or rooms, have either a ventilation system that is separate from the rest of the hospital or a means of preventing the unfiltered exhaust air of the radiation emergency area from mixing with the air that is distributed to the rest of the hospital, there is very little likelihood that contaminants will become suspended in air and enter the ventilation system. Hence, no special precautions are advised. (Ref.: AMA. *A Guide To The Hospital Management Of Injuries Arising From Exposure To Or Involving Ionizing Radiation*. 1984).



## Hospital Emergency Care of the Radiation Accident Patient

### Patient arrival and triage

Meet the radiation accident victim at the ambulance or at a triage area established near the treatment area. Instruct EMS personnel to stay with their vehicle until they, their vehicle, and equipment are surveyed and released by a radiation safety officer.

During triage, consideration is given to medical and radiological problems. **Serious medical problems always have priority over radiological concerns**, and immediate attention is directed to life-threatening problems. Radiation injury rarely causes unconsciousness or immediate visible signs of injury and is not immediately life threatening; therefore other causes of injury or illness **must** be considered.

**Noncontaminated** patients are admitted to the usual treatment area. **Contaminated** patients are admitted to a specially prepared area. When in doubt, a critically injured patient should be taken immediately into the prepared area. If the victim's condition allows, an initial, **brief** radiological survey can be performed to determine if the victim is contaminated. Any radiation survey meter reading above background radiation levels indicates the possibility of contamination. A more thorough survey will be performed once life-threatening problems are addressed.

The victim's contaminated clothing should be removed before arrival at the hospital (at the accident scene), if this can be accomplished without causing harm or delay. Otherwise, the clothing should be removed as promptly as possible (without compromising life or limb), using care to avoid spread of any contaminants embedded in or on the clothing. Clothing, and any accompanying sheets, blankets, etc. should be placed in a plastic bag. Care-givers should change gloves after handling clothing or other potentially contaminated items.

### Assessment and treatment of the noncontaminated patient

Noncontaminated individuals can be cared for like any other emergency case. A specially prepared treatment area is not needed. Following attention to medical needs, question the patient to determine the possibility of radiation exposure from an external source. Remember, the victim of exposure without contamination poses no radiological hazard to anyone. If exposure is known or suspected, a stat CBC should be ordered with particular attention given to determining the absolute lymphocyte count. Be sure to record the time the blood sample is taken. For differential diagnosis, refer to acute radiation injury [see below under "Acute Radiation Syndrome"].

### Assessment and treatment of the contaminated patient

Contaminated patients can have radioactive materials deposited on skin surfaces, in wounds, or internally (ingested, inhaled, or absorbed). Reassessment of the contaminated patient's airway, breathing, and circulation are done in the decontamination room prior to attention to the patient's radiological status. Level of consciousness and vital signs are assessed promptly and the patient's condition is stabilized. After examining the entire patient and identifying all injuries, a complete radiological survey should be done.

The patient should be questioned about allergies, currently used medications, any history of chronic or recent illness, and **recent nuclear medicine tests [or radioactive seed implants]**. The patient's level of anxiety should be noted, and psychological support offered. A complete and detailed medical, occupational, and accident history should be taken, and a physical examination completed.

Certain clinical and radiological laboratory analyses (see Radiological and Clinical Laboratory Assessments section below) are essential to the care of the radiation accident patient. These laboratory tests are done to assess the biological effects of radiation injury; to identify abnormalities that might complicate treatment; to locate, identify, and quantify radionuclide contamination; and to provide information useful in accident analysis.

### Radiological and clinical laboratory assessments

All samples must be placed in separate, labeled containers that specify name, date, time of sampling, area of samples, and size of area samples. It is suggested that blood, urine, feces, or other samples taken in the emergency treatment period be retained for subsequent investigation. Appropriate advice (legal, radiation safety, etc.) should be obtained regarding the storage and disposition requirements of collected samples.

[The following table describes the samples that need to be obtained in all cases of radiation injury.]

Samples Needed	Why?	How?
<b><i>In all cases of radiation injury:</i></b>		
CBC and differential STAT (follow with absolute lymphocyte counts every 6 hours for 48 hours when history indicates possibility of total-body irradiation)	To assess the radiation dose; initial counts establish a baseline, subsequent counts reflect the degree of injury	Choose a noncontaminated area for venipuncture; cover puncture site after collection
Routine urinalysis	To determine if kidneys are functioning normally and establish a baseline of urinary constituents; especially important if internal contamination is a possibility	Avoid contaminating specimen during collection; if necessary, give the patient plastic gloves to wear for collection of specimen; label specimen "Number 1," with date and time

[The table on the following page describes additional samples needed when external and/or internal contamination is suspected.]

Samples Needed	Why?	How?
<b>When external contamination is suspected:</b>		
Swabs from body orifices	To assess possibility of internal contamination	Use separate saline- or water-moistened swabs to wipe the inner aspect of each nostril, each ear, mouth, etc.
Wound dressing and/or swabs from wounds	To determine if wounds are contaminated	Save dressings in a plastic bag. Use moist or dry swabs to sample secretions from each wound, or collect a few drops of secretion from each using a dropper or syringe; for wounds with visible debris, use applicator or long tweezers or forceps to transfer samples to specimen containers which are placed in lead storage containers (pigs)
<b>When internal contamination is suspected:</b>		
Urine: 24-hour specimen x 4 days	Body excreta may contain radionuclides if internal contamination has occurred	Use 24-hour urine collection container
Feces x 4 days		

### Decontamination of the contaminated patient

Good judgment is essential in determining decontamination priorities. Since some radioactive materials are corrosive or toxic because of their chemical properties, medical attention might have to be directed first to a non-radiological problem if radioactive materials are components of acids, fluorides (uranium hexafluoride-UF<sub>6</sub>), mercury, lead, or other compounds.

In general, contaminated wounds and body orifices are decontaminated first, followed by areas of highest contamination levels on the intact skin. The purpose of decontamination is to prevent or reduce incorporation of the material (internal contamination), to reduce the radiation dose from the contaminated site to the rest of the body, to contain the contamination, and to prevent its spread. Please note that frequent glove changes will be necessary.

### • Treatment of contaminated wounds

In a contamination accident, any wound must be considered contaminated until proven otherwise and **should be decontaminated prior to decontaminating intact skin**. When wounds are contaminated, the physician must assume that uptake (internal contamination) has occurred. Appropriate action is based on half-life, radiotoxicity, and the amount of radioactive material. It is important to consult experts as soon as possible and to initiate measures that prevent or minimize uptake of the radioactive material into body cells or tissues.

Contaminated wounds are first draped, preferably with a waterproof material, to limit the spread of radioactivity. Wound decontamination is accomplished by gently irrigating with saline or water. More than one irrigation is usually necessary. The wound should be monitored after each irrigation. Contaminated drapes, dressings, etc., should be removed before each monitoring for accurate results. When monitoring contaminated wounds or irrigation fluids, gamma radiation is easily detected while beta radiation may prove more difficult to detect. Without special, highly sophisticated wound probes, alpha contamination will not be detected. Following repeated irrigations, the wound is treated like any other wound. If the preceding decontamination procedures are not successful, and the contamination level is still seriously high, conventional debridement of the wound must be considered. Excision of vital tissue should not be initiated until expert medical or health physics advice is obtained. Debrided or excised tissue should be retained for health physics assessment.

Embedded radioactive particles, if visible, can be removed with forceps or by using a water-pik. Puncture wounds containing radioactive particles, especially in the fingers, can be decontaminated by using an "en bloc" full thickness skin biopsy using a punch biopsy instrument.

After the wound has been decontaminated, it should be covered with a waterproof dressing. The area around the wound is decontaminated as thoroughly as possible before suturing or other treatment.

Contaminated burns (chemical, thermal) are treated like any other burn. Contaminants will slough off with the burn eschar. However, dressings and bed linens can become contaminated and should be handled appropriately.

### • Decontamination of body orifices

Contaminated body orifices, such as the mouth, nose, eyes, and ears need special attention because absorption of radioactive material is likely to be much more rapid in these areas than through the skin.

If radioactive material has entered the oral cavity, encourage brushing the teeth with toothpaste and frequent rinsing of the mouth. If the pharyngeal region is also contaminated, gargling with a 3-percent hydrogen peroxide solution might be helpful. Gastric lavage may also be used if radioactive materials were

swallowed. Contaminated eyes should be rinsed by directing a stream of water from the inner canthus to the outer canthus of the eye while avoiding contamination of the nasolacrimal duct. Contaminated ears require external rinsing, and an ear syringe can be used to rinse the auditory canal, provided the tympanic membrane is intact.

- External contamination

**Decontamination of the intact skin** is a relatively simple procedure. Complete decontamination, which returns the area to a background survey reading, is not always possible because some radioactive material can remain fixed on the skin surface. Decontamination should be only as thorough as practical.

Decontamination should begin with the least aggressive method and progress to more aggressive ones. Whatever the procedure, take care to limit mechanical or chemical irritation of the skin. The simplest procedure is to wash the contaminated area gently under a stream of water (do not splash) and scrub at the same time using a soft brush or surgical sponge. Warm, never hot, tap water is used. Cold water tends to close the pores, trapping radioactive material within them. Hot water causes vasodilation with increased area blood flow, opens the pores, and enhances the chance of absorption of the radioactive material through the skin. **Aggressive rubbing tends to cause abrasion and erythema and should be avoided.**

If washing with plain water is ineffective, a mild soap (neutral pH) or surgical scrub soap can be used. The area should be scrubbed for 3 to 4 minutes, then rinsed for 2 to 3 minutes and dried, repeating if necessary. Between each scrub and rinse, check the contaminated area to see if radiation levels are decreasing. Sodium hypochlorite, diluted 1 to 10 with water, is an effective decontamination agent. A mildly abrasive soap (a 1 to 1 mixture of powdered detergent and cornmeal mixed with water into a paste) can be used for calloused areas. **The decontamination procedure stops when the radioactivity level cannot be reduced to a lower level.** Expert advice might be needed to determine an appropriate stopping point. Contaminated hairy areas can be shampooed several times. Contaminated hair can be clipped if shampooing is ineffective. Shaving should be avoided since small nicks or abrasions can lead to internal contamination. When shampooing the head, avoid getting any fluids into the ears, eyes, nose, or mouth.

Ambulatory patients with localized contamination can be decontaminated using a sink or basin. If extensive body areas are contaminated, the patient can be showered under the direction or with the assistance of a radiation safety officer. Caution the patient to avoid splashing water into the eyes, nose, mouth, or ears. Repeated showers might be necessary, and clean towels provided for drying after each shower. Again, decontamination should be as thorough as practical.

Although it may be desirable that the wastewater from decontamination procedures be retained and analyzed before being discharged into the sanitary sewer, this requirement should not be mandatory. Furthermore, the installation of an elaborate holding system is not likely to be justified because of the infrequency of the event. The welfare of the patient should come first, and the physician should feel free to use whatever facilities are readily available to accomplish that end. Any radiation hazard to the general public will be virtually eliminated when the inherently small and infrequent volume of radioactive waste is mixed with and diluted by other sewage effluents of the hospital and community (AMA, 1984).

### **Patient comfort and emotional support**

A patient involved in a radiation accident needs explanations of procedures and actions being taken (isolation, use of survey meters, taking of samples, decontamination, etc.) in the radiation emergency area. A knowledgeable person should answer the patient's questions and provide reassurance. For example, explain use of protective clothing and surgical masks during treatment. Following initial care and treatment, someone with a knowledge of radiation effects should spend adequate time answering the patient's questions. Preferably, this person should be the attending physician who continues to treat the patient until discharge. Reporters and news-hunters should get their reports from the hospital's public information officer.

### **Patient safety**

Routine precautions for patient safety should not be forgotten. Be especially alert for potential falls or slips on wet floors, excessive heating or chilling, and electrical hazards.

### **Documentation**

In addition to routine medical records, note survey readings, samples taken (and time), descriptions of the accident, and the effectiveness of decontamination. Take care to note pre-existing conditions such as rashes, healing wounds, or scars. This information will be extremely valuable to medical consultants and health physicists in reconstructing the accident accurately and making a prognosis.

### **Post-emergency patient transfer**

A final complete-body survey is performed following decontamination procedures. A new floor covering is laid from the clean area to the patient stretcher. A clean stretcher is brought in, the patient is transferred to it by clean attendants (those involved in the decontamination procedure may now be contaminated), and the patient is wheeled to the door. After the radiation safety officer makes a final check of the patient and the stretcher (especially the wheels), the patient is taken from the room.



### Staff exit from the controlled area

Each member of the decontamination team goes to the control line and removes his protective clothes as described below:

1. Remove outer gloves first, turning them inside-out as they are pulled off.
2. Give dosimeter to radiation safety officer.
3. Remove all tape at trouser cuffs and sleeves.
4. Remove outer surgical gown, turning it inside-out -- avoid shaking.
5. Pull surgical trousers off over shoe covers.
6. Remove head cover and mask.
7. Remove shoe cover from one foot and let radiation safety officer monitor shoe; if shoe is clean, step over control line, then remove other shoe cover and monitor other shoe.
8. Remove inner gloves.
9. Do total-body radiological survey of each team member.
10. Take shower.

After staff exit, the decontamination room should be secured and a sign reading **"CAUTION -- CONTROLLED AREA -- DO NOT ENTER"** should be posted. Unless it is needed for emergency medical reasons, the decontamination room remains secured until it can be checked and decontaminated, if necessary, by the radiation safety officer or other health physics expert.

### Radiation Injury

Exposure to high levels of penetrating radiation can involve the whole body (uniformly or nonuniformly), a significant portion of the body, or a small, localized part. The exposure can be acute, protracted, or fractionated over time.

#### Local Injury

**Most radiation injuries are "local" injuries**, frequently involving the hands. These local injuries seldom cause the classical signs and symptoms of the acute radiation syndrome.

Consider local radiation injury in the differential diagnosis if the patient presents with a skin lesion without a history of chemical or thermal burn, insect bite, or history of skin disease or allergy. If the patient gives a history of possible radiation exposure (such as from a radiography source, X-ray device, or accelerator) or a history of finding and handling an unknown metallic object, note the presence of any of the following: erythema, blistering, dry or wet desquamation, epilation, ulceration. Local injuries to the skin evolve very slowly over time and symptoms may not manifest for days to weeks after exposure.

Conventional wound management is usually ineffective in these cases. **Consultation with experts regarding definitive diagnosis, tissue dose, treatment, and prognosis is recommended.**

### Acute Radiation Syndrome

Acute radiation syndrome (ARS) is an acute illness caused by irradiation of the whole body (or a significant portion of it). It follows a somewhat predictable course and is characterized by signs and symptoms which are manifestations of cellular deficiencies and the reactions of various cells, tissues, and organ systems to ionizing radiation.

Immediate, overt manifestations of the acute radiation syndrome require a large (i.e., hundreds of rem, usually whole-body) dose of penetrating radiation delivered over a short period of time. Penetrating radiation comes from a radioactive source or machine that emits gamma rays, X-rays, or neutrons. The signs and symptoms of this syndrome are non-specific and may be indistinguishable from those of other injuries or illness.

The ARS is characterized by four distinct phases: a prodromal period, a latent period, a period of illness, and one of recovery or death. During the prodromal period patients might experience loss of appetite, nausea, vomiting, fatigue, and diarrhea; after extremely high doses, additional symptoms such as fever, prostration, respiratory distress, and hyperexcitability can occur. However, all of these symptoms usually disappear in a day or two, and a symptom-free, latent period follows, varying in length depending upon the size of the radiation dose. A period of overt illness follows, and can be characterized by infection, electrolyte imbalance, diarrhea, bleeding, cardiovascular collapse, and sometimes short periods of unconsciousness. Death or a period of recovery follows the period of overt illness.

In general, the higher the dose the greater the severity of early effects and the greater the possibility of late effects.

Depending on dose, the following syndromes can be manifest:

- Hematopoietic syndrome - characterized by deficiencies of WBC, lymphocytes and platelets, with immunodeficiency, increased infectious complications, bleeding, anemia, and impaired wound healing.
- Gastrointestinal syndrome - characterized by loss of cells lining intestinal crypts and loss of mucosal barrier, with alterations in intestinal motility, fluid and electrolyte loss with vomiting and diarrhea, loss of normal intestinal bacteria, sepsis, and damage to the intestinal microcirculation, along with the hematopoietic syndrome.
- Cerebrovascular/Central Nervous System syndrome - primarily associated with effects on the vasculature and resultant fluid shifts. Signs and symptoms include vomiting and diarrhea within minutes of exposure, confusion, disorientation, cerebral edema, hypotension, and hyperpyrexia. Fatal in short time.
- Skin syndrome - can occur with other syndromes; characterized by loss of epidermis (and possibly dermis) with "radiation burns."

[The second table on the last page of this document, which was taken from a Department of Veterans Affairs fact sheet, contains additional summary information on acute radiation syndrome.]

#### Initial Emergency Management:

- If trauma is present, treat.
- If external contaminants are present, decontaminate.

#### Diagnosis:

- History of exposure - consider acute radiation syndrome in the differential diagnosis if there is:
  - a history of a known or possible radiation exposure (for example, entering an irradiation chamber when the source is unshielded)
  - a history of proximity to an unknown (usually metallic) object with a history of nausea and vomiting, especially if n/v are unexplained by other causes
  - a tendency to bleed (epistaxis, gingival bleeding, petechiae) and/or respiratory infection with neutropenia, lymphopenia, and thrombocytopenia, with history of nausea and vomiting two to three weeks previously
  - epilation, with a history of nausea and vomiting two to three weeks previously
- Symptom - type of symptom, time of onset, severity, and frequency.

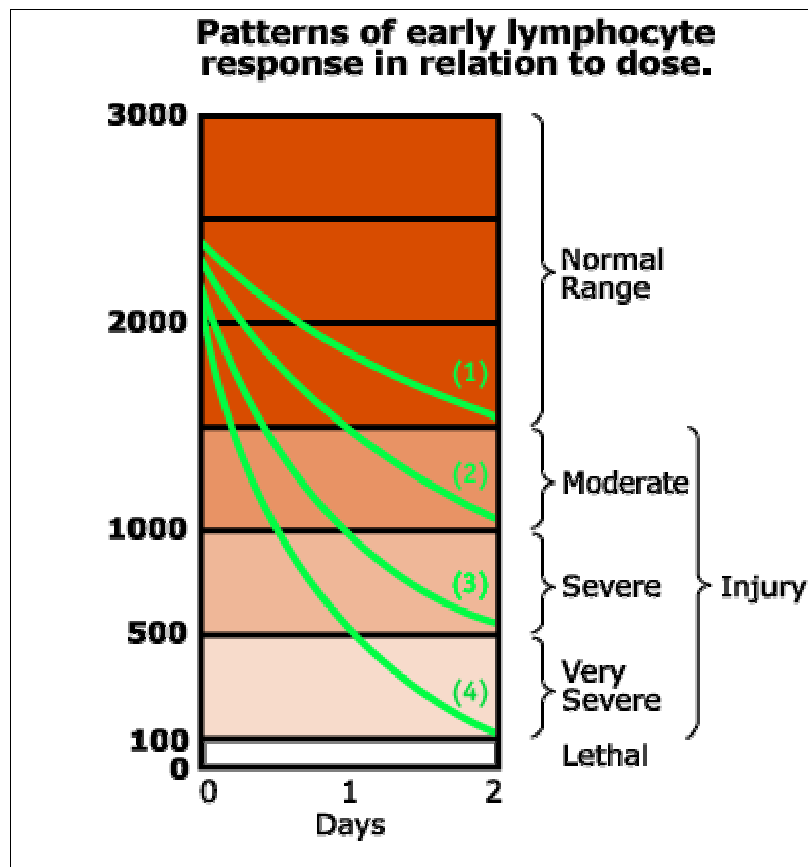
- Clinical lab - STAT CBC with differential. Repeat in 4-6 hours, then every 6-8 hours for 24-48 hours. Look for a drop in the absolute lymphocyte count if the exposure was recent (see figure, below). If the initial WBC and platelet counts are abnormally low, consider the possibility of exposure a few days to weeks earlier.

#### Acute Radiation Syndrome: Dose Less Than 2 Gy (200 rad)

Nausea and vomiting due to radiation are seldom experienced unless the exposure has been at least 0.75-1 Gy (75-100 rads) of penetrating gamma or X-rays and it has occurred within a matter of a few hours or less. The prospective patient who has been asymptomatic within the past 24 hours will most certainly have had less than 0.75 Gy of whole-body exposure. Hospitalization generally will be unnecessary if the dose has been less than 2 Gy (200 rads).

#### Management of ARS (dose <2 Gy):

- Close observation and frequent CBC with differential.
- Outpatient management may be appropriate.
- Provide instructions regarding home care.



**Figure.** Classical Andrews lymphocyte depletion curves and accompanying clinical severity ranges. According to the data presented in this paper, curves 1-4 correspond roughly to the following whole-body doses:

- curve 1 - 3.1 Gy;
- curve 2 - 4.4 Gy;
- curve 3 - 5.6 Gy;
- curve 4 - 7.1 Gy.

From Goans, Ronald E., Holloway, Elizabeth C., Berger, Mary Ellen, and Ricks, Robert C. "Early Dose Assessment Following Severe Radiation Accidents," *Health Physics* 72(4): 1997.

### Acute Radiation Syndrome: Dose Greater Than 2 Gy (200 rad)

Signs and symptoms become increasingly severe with dose.

- Hematopoietic Syndrome:

- The prodromal phase - nausea, vomiting and anorexia within a few hours at the higher dose levels, or after 6 to 12 hours at the lower dose levels. Lasts 24 to 48 hours, after which time the patient is asymptomatic and may feel well. The absolute lymphocyte count will fall; a stress response of WBC may be present.
- The latent phase - lasts a few days to as long as 2 to 3 weeks at the lower dose levels. The patient is asymptomatic but CBCs will show characteristic changes in the blood elements, with lymphocyte depression and gradual decrease in neutrophil and platelet counts.
- A bone marrow depression phase requires sophisticated treatment. Infection and hemorrhage could occur when white cell and platelet counts become critically low.
- The recovery phase - stem cells in the bone marrow are never completely eradicated at 2 to 10 Gy (200 to 1000 rads); some may replicate and eventually produce sufficient blood elements. Supportive therapy is required.

- Gastrointestinal Syndrome:

- Over 10 Gy (1000 rads) - this syndrome is distinguishable from the hematopoietic syndrome by the immediate, prompt and profuse onset of nausea, vomiting and diarrhea, followed by a short latent period. GI symptoms recur and lead to marked dehydration, and vascular effects. The GI mucosa becomes increasingly atrophic, and massive amounts of plasma are lost to the intestine. Massive denuding of the GI tract and accompanying septicemia and dehydration can occur. If the patient survives long enough, depression of the hematopoietic system occurs and complicates the clinical course.

- Cardiovascular Syndrome:

- Over 30 Gy (3000 rads), an extremely high dose, to the whole-body. Always fatal, there is immediate nausea, vomiting, anorexia and prostration, and irreversible hypotension; blood pressure will be markedly unstable. Within hours after exposure, the victim will be listless, drowsy, tremulous, convulsive, and ataxic. Death most likely will occur within a matter of days.

### Management of Acute Radiation Syndrome (Dose >2 Gy)

#### Initial management:

- Vomiting - use selective blocking of serotonin 5-HT<sub>3</sub> receptors or use 5-HT<sub>3</sub> receptor antagonists.
- Consider initiating viral prophylaxis.

- Consider tissue, blood typing.
- Treat trauma.
- Consider prompt consultation with hematologist and radiation experts, re: dosimetry and prognosis, use of colony stimulating factors, stem cell transfusion, and other treatment options.
- Draw blood for chromosome analysis; use heparinized tube.
- Note areas of erythema and record on body chart. If possible, take photographs.

#### Begin, as indicated:

- SUPPORTIVE CARE in a CLEAN environment (reverse isolation).
- Prevention and treatment of infections.
- Stimulation of hematopoiesis (use of growth factors, i.e., GCSF, GMCSF, interleukin 11).
- Stem cell transfusions: cord blood, peripheral blood, or bone marrow. Platelet transfusions if bleeding occurs or if platelet count too low.
- Psychological support.
- Observe carefully for erythema (document locations), hair loss, skin injury, mucositis, parotitis, weight loss, and/or FEVER.
- Consultation with experts in radiation accident management is encouraged.

### **Treatment of Internal Contamination**

Once radioactive materials cross cell membranes, they are said to be incorporated. Incorporation is a time-dependent, physiological phenomenon related to both the physical and chemical natures of the contaminant. Incorporation can be quite rapid, occurring in minutes, or it can take days to months. Thus, time can be critical and prevention of uptake is urgent. Several methods of preventing uptake (e.g., catharsis, gastric lavage) might be applicable and can be prescribed by a physician. Some of the medications or preparations used in decorporation might not be available locally and should be stocked when a decontamination station is being planned and equipped. Examples of specific agents used for selected radionuclides can be seen in the table below. Expert guidance is available from NCRP 65, poison control centers, or call REAC/TS (865-576-3131) or the 24-hour emergency number (865-576-1005).

If internal contamination is suspected or has occurred, the physician or radiation safety officer should request samples of urine, feces, vomitus, wound secretion, etc. Whole-body counting and radioassay can help evaluate the magnitude of the problem and the effect of any treatment. The contaminated patient admitted with an airway or endotracheal tube must be considered to be internally contaminated.

[The first table on the following page provides a summary of treatment for selected internal contaminants. The second table, from a Department of Veterans Affairs fact sheet, contains summary information on acute radiation syndrome.]

### Treatment for Selected Internal Contaminants

Radionuclide	Medication	For Ingestion/Inhalation	Principle of Action
Iodine	KI (potassium iodide)	130 mg (tabl) stat, followed by 130 mg q.d. x 7 if indicated	Blocks thyroid deposition
Rare earths Plutonium Transplutronics Yttrium	<a href="#">Zn-DTPA</a> <a href="#">Ca-DTPA</a>	1 gm Ca-DTPA (Zn-DTPA) in 150-250 ml 5 percent D/W IV over 60 minutes	Chelation
Uranium	Bicarbonate	2 ampules sodium bicarbonate (44.3 mEq each; 7.5%) in 1000 cc normal saline @ 125 cc/hr; alternately, oral administration of two bicarbonate tablets every 4 hours until the urine reaches a pH of 8-9	Alkalinization of urine; reduces chance of acute tubular necrosis
Cesium Rubidium Thallium	Prussian Blue [Ferrihexacyano-Ferrate (II)]	1 gm with 100-200 ml water p.o. t.i.d. for several days	Blocks absorption from GI tract and prevents recycling.
Tritium	Water	Force fluids	Isotopic dilution

### Acute Radiation Syndrome

1 Gray (Gy) = 100 rads      1 centiGray (cGy) = 1 rad

Whole body radiation from external radiation or internal absorption							
Phase of Syndrome	Feature	Subclinical range		Sublethal range		Lethal range	
		0 – 100 rad or cGy	100-200 rad 1-2 Gy	200-600 rad 2-6 Gy	600-800 rad 6-8 Gy	800-3000 rad 8-30 Gy	>3000 rad >30 Gy
<b>Prodromal Phase</b>	Nausea, vomiting	none	5-50%	50 - 100%	75-100%	90-100%	100%
	Time of onset		3-6 hrs	2-4 hrs	1-2 hrs	<1 hr	Minutes
	Duration		<24 hrs	<24 hrs	<48 hrs	<48 hrs	N/A
	Lymphocyte count	Unaffected	Minimally decreased	< 1000 at 24 hr	< 500 at 24hr	Decreases within hours	Decreases within hours
	CNS function	No impairment	No impairment	Cognitive impairment for 6-20 hrs	Cognitive impairment for >24 hrs	Rapid incapacitation, often after a lucid period of up to several hours	
<b>Latent Phase (subclinical)</b>	Absence of Symptoms	> 2 wks	7-15 days	0-7 days	0-2 days	None	
<b>Acute Radiation Illness or "Manifest illness" phase</b>	Signs and symptoms	none	Moderate leukopenia	Severe leukopenia, purpura, hemorrhage Pneumonia Hair loss after 300 rad/3 Gy		Diarrhea Fever Electrolyte disturbance	Convulsions, Ataxia, Tremor, Lethargy
	Time of onset		> 2 wks	2 days - 2 wks		1-3 days	
	Critical period		none	4-6 wks - Most potential for effective medical intervention		2-14 days	1-48 hrs
	Organ system	none		Hematopoietic and respiratory (mucosal) systems		GI tract Mucosal systems	CNS
<b>Hospitalization</b>	% Duration	0	<5% 45-60 days	90% 60-90 days	100% 90+ days	100% weeks to months	100% days to weeks
<b>Mortality</b>		None	Minimal	Low with aggressive therapy	High	Very high, significant neurological symptoms indicate lethal dose	

From: *Terrorism With Ionizing Radiation General Guidance - Pocket Guide*, Department of Veterans Affairs, August 2003.